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Gypsy Moth Manual

Appendix I

Methods for Gypsy Moth Eradication

Overview

This appendix contains information on the following topics:

- Approved methods for the eradication of gypsy moth
- Biological insecticides used in eradications
- Chemical insecticides used in eradications
- Behavioral methods used in eradications
- Experimental treatments considered for use in eradications or control treatments are briefly covered in this appendix, even though they are not presently approved.

Approved Methods and the Final Environmental Impact Statement (FEIS)

The Final Environmental Impact Statement (FEIS), published in November 1995, has designated the treatments approved for gypsy moth eradication. The title of the 1995 FEIS is *Gypsy Moth Management in the United States: A Cooperative Approach*.

The treatments approved in the FEIS for eradications are the following:

- Biological insecticides
    - *Bacillus thuringiensis* var. *kurstaki* (Btk)
    - Nucleopolyhedrosis virus (NPV) (Used in Gypchek)

- Chemical insecticides
  - Diflubenzuron (Dimilim®)
  - Tebufenozide (Note: Confirm® was developed after the FEIS.)
- Behavioral treatments
  - Mass trapping
  - Mating Disruption

These approved methods may be used alone or in combination.

Biological Insecticides Used in Eradications

Bacillus thuringiensis var. *kurstaki* (*Btk*)

Background: *Bacillus thuringiensis* (*Bt*) is a rod-shaped bacterium that forms resting spores. Unique to this species is the formation of a protein crystal next to the resting spore during spore formation. *Bt* occurs naturally in soils throughout the world. A strain of *Bt*, called variety *kurstaki* and known as *Btk*, is effective as a control agent for defoliating forest caterpillars.

After gypsy moth larvae ingest the *Btk* spores and protein crystals, the protein crystals dissolve in the gut causing disruption of the gut lining, ultimately resulting in perforation of the gut and leakage of the gut contents. The gypsy moth larvae stops feeding because of the damage to their digestive tracts. Death occurs within a few hours or days.

Use: *Btk* is the insecticide of choice for eradicating isolated infestations of the gypsy moth. For eradications, the typical dose rate is 24 BIU per acre (60 BIU/ha) applied two to three times.

There are several formulations of *Btk* that can be used in eradication projects:

- Foray® 48B
- Foray® 48F
- Foray® 76B
- Thuricide® 48LV

The effectiveness of the *Btk* application will depend on proper timing. The timing of the applications must match the following factors:

- The development of the most susceptible larval instars
- The period of expanding foliage
- A period of favorable weather (dry conditions)

Smaller instars of the larvae are more susceptible than larger instars. Application is best when the majority of the larvae are in the second instar. Application must **not** be delayed beyond the early third instar. As a rule, application is often done when 30% of the larvae are in the first instar, 50% are in the second instar, and 20% are in the third instar.

Btk application is done on expanding leaves. Typically, application is best when the leaves of the red oak are 45% to 60% expanded. An old rule states that for the first application foliage should have expanded to at least one-quarter to one-half.

Phenology models can be used to help predict insect development, so that *Btk* can be applied at the most opportune time.

Dry conditions must prevail during and after application.

Effectiveness: Because *Btk* causes gut paralysis and cessation of feeding by gypsy moth larvae, it is well suited as a means of reducing the gypsy moth population. Great reductions in gypsy moth populations occur with the high dose rates used in eradication projects.

On the negative side, *Btk* has varying degrees of toxicity to larval stages of most moths and butterflies. For example, *Btk* treatments reduce both richness and abundance of native lepidopterans, particularly those species with larvae present early in the season when gypsy moth is present.

Nucleopolyhedrosis virus (NPV) (Used in Gypchek)

The nucleopolyhedrosis virus (NPV) that affects gypsy moth is native to North America. The virus is a member of the Genus *Baculovirus* and is unrelated to arthropod-borne viruses and other viruses that infect man. The virus is specific to gypsy moth and causes a disease that can drastically reduce gypsy moth populations, particularly when high gypsy moth populations and high levels of viral inoculum occur together. In dense gypsy moth populations, the virus may kill up to 90% of the larvae. The virus appears to spread rather easily when egg masses are laid on surfaces contaminated with the virus.

In 1978 Gypchek, a virus-containing biological insecticide, was registered with the U. S. Environmental Protection Agency (U. S. EPA)

Use: Gypchek must be formulated at the mixing and loading site before application. The standard tank mix consists of water (pH 5.0-8.0), an ultraviolet light sunscreen (a lignan Sulfate product), a feeding stimulant (molasses), and a sticking agent (to aid adhesion to leaf surfaces).

In 1995, Novo Nordisk (now?) developed a commercially produced and ready-to-use carrier called Carrier 138. This new carrier is easier to mix and apply, as well as giving superior ultraviolet protection and spray deposition patterns. Lower spray volumes can be applied without sacrificing efficacy.

NOTICE

Care must be taken in the mixing and application of Gypchek. Stickers and UV protectants must be used to enhance the performance of this product. Apply Gypchek aerially in sufficient spray mixture for thorough and uniform coverage.

Application information for Gypchek is as follows:

- Application rate: 2 x 10^{11} to 2 x 10^{12} occlusion bodies (OB) in 1.0 gallon of spray mixture per acre (4.9 x 10^{11} to 2.47 x 10^{12} OB per 9.34 L/ha) per application
- Number of Applications: Two applications, 3 days apart are recommended during an eradication
- Nozzles (Check from old manual): Use boom and nozzle systems designed to result in droplets of 150-400 mass media diameter (for example, flat fan 8006, Beecomist 275 or Micronair AU5000)
- Water pH: 5.0-8.0
- (If not in Carrier 138?) Molasses (PRO MO®)--0.125 gallon (16 fl. oz.)
- (If not in Carrier 138?)Rhoplex® B60A (sticker)--3 fl. oz.
- (If not in Carrier 138?)Orzan LS® (48 percent solution)—0.125 gallon (16 fl. oz.) (or use Orzan LS® powder--0.5 lb. per gallon)

CAUTION

Check pH of water from field source. If pH exceeds 8.0 or is below 5.0, add sufficient acid or base to adjust pH to approximately 7.0

NEVER USE CHLORINATED WATER IN THE SPRAY FORMULATION.

Mixing sequence for conventional mixing equipment, if Carrier 138 is not used.

Step 1—Fill tank with water and start agitation.

Step 2—Before mixing pesticide, check and adjust the pH within the range of pH 6.0 to 7.0.

You can use commercially available phosphoric acid (85 percent) to lower pH. One ounce of phosphoric acid will adjust 500 gallons of water from a pH of 9.0 to an acceptable level (between 6.0 and 7.0).

Step 3—Add sunscreen Orzan LS by slowly pouring into water.

Step 4—Add molasses by slowly pouring into the water and mix thoroughly.

Step 5—Add sticker and mix thoroughly.—

Step 6—Add Gypchek and mix thoroughly for 15 to 20 minutes before loading aircraft.

NOTICE

Read label thoroughly before using. Follow all label cautions and directions.

Effectiveness: Because Gypchek is specific for gypsy moth and does not affect other lepidopteran species or nontarget organisms that might be in the treatment area, Gypchek is a desirable insecticide to use where threatened and endangered species might be found or where is environment is environmentally sensitive.

The availability of Gypchek is limited. The Forest Service and APHIS produce quantities sufficient to treat about 20,000 acres (8.1 hectares) each year.

Chemical Insecticides Used in Eradications

Diflubenzuron

Background: Sold under the name Dimilin®, diflubenzuron belongs to the group of compounds called insect growth regulators (IGRs). When ingested by gypsy moth larvae, diflubenzuron disrupts the formation of a new cuticle (outer skin) during molting. The larvae cannot complete the molting process, their body walls rupture from internal pressure, and the larvae die.

Use: Both aerial and ground applications are used in eradication projects. Since 1994, Dimilin® 4L is the sole formulation for use in gypsy moth projects.

Typically, aerial application of diflubenzuron in eradication projects is 0.5 ounces active ingredient in 0.75-1.00 gallons spray volume per acre, applied twice.

Effectiveness: Diflubenzuron effectively reduces gypsy moth populations and protects foliage.

Diflubenzuron is a “restricted use” pesticide because of its toxicity to aquatic invertebrate animals. Therefore, only certified pesticide applicators can buy this insecticide, and use of this insecticide is only by certified operators and those under their direct supervision.

Tebufenozide

Background: Sold under the name Confirm® T/0, tebufenozide mimics the action of a natural insect hormone which induces molting and metamorphosis. In effect, Tebufenozide controls lepidopterous larvae by inducing lethal, premature molts (Confirm® T/0, Label, 2001)

Use: Application of tebufenozide must be in a manner that ensures uniform and thorough coverage.

Reapplication may be required to protect new flushes of foliage.

The label of Confirm® T/O states that the following spray adjuvants have been especially formulated to optimize the performance of foliar-applied agricultural chemicals and are recommended for use with Confirm® T/0:

Latron® B-1956	◆ Effective with dilute sprays applied by ground equipment
Latron® CS-7	◆ A spreader-binder designed specifically for use in concentrate and low-volume sprays applied by aircraft or ground equipment

Effectiveness: While tebufenozide is essentially equally effective against all instars, it is generally good practice to avoid the heavy damage that can be inflicted by later instar larvae (Confirm® T/O label, 2001)

Behavioral Treatments Used in Eradications

Mass Trapping

Background: Mass trapping uses the synthetic sex pheromone, disparlure, to attract male moths to traps that have been placed in a grid pattern across the treatment area. The objective of mass trapping is to capture male gypsy moths before they have a chance to locate and mate with female moths.

Mass trapping is most effective when used to eradicate low population densities. As an eradication method, mass trapping can be used alone or with other methods of eradication. For example, the majority of eradications use mass trapping after insecticide application.

Use: Mass trapping involves using an aggressive trapping grid of 3 to 10 traps per acre.

If the core area of the infestation is known, then increased trapping densities in the core area will be at the level of 10 traps per acre.

Two types of traps are used depending on the expected number of moths that might be caught:

- The standard “delta” trap is a small capacity trap about 8 inches (20 cm) long, 4 inches (10 cm) high, and triangular in cross section. To lure the male moth, a tiny plastic strip or wick impregnated with the pheromone is stapled to the inside of the trap. To entrap the male moths, a sticky substance coats the inside surface of the trap.
- The “milk-carton” trap, so called because it resembles a milk carton, is used in areas where large numbers of male moths would quickly overwhelm the sticky surface of the smaller delta trap. Like the delta trap, a small pheromone plastic strip or wick is placed inside the milk-carton trap to lure the male moth. Unlike the delta trap, the milk-carton traps contains a 1-inch by 4-inch (2.5 x 10 cm) laminated plastic strip that contains the insecticide dichlorvos (DDVP). When used in milk-carton traps DDVP is formulated and registered as Vaportape II (Hercon Environmental Company, Emigsville, PA).

Effectiveness: The higher the population density, the greater the risk that a male will find and mate with a female before being lured into a trap. Therefore, treatment is best used where there are less than 10 egg masses per acre (25 egg masses per hectare).

Mass trapping is a labor-intensive treatment, especially over large areas. Therefore, it is typically used on small infestations less than 100 acres (40.4 hectares).

Mass trapping does **not** affect nontarget organisms, except those (primarily flying insects) that accidentally find their way into the traps.

In residential areas with small infestations, mass trapping is an alternative to using insecticides. Mass trapping is an option where there is strong resistance to using insecticides.

Mating Disruption

Background: The objective of mating disruption is to saturate the treatment area with enough pheromone sources to confuse the male moths and thereby prevent them from finding and mating with female moths.

Use: Mating disruption can be accomplished by either ground or aerial application of disparlure:

- In ground applications, distribution of disparlure is by distribution of laminated polymeric dispensers or tapes that are impregnated with the pheromone. From the laminated polymeric dispensers and tapes, the pheromone is slowly released into the environment. Because the laminated polymeric dispensers and tapes must be manually attached to trees, this method is labor intensive.
- In aerial applications, distribution of disparlure is by distribution of dispensers. One type of dispenser is the small (0.1 inch; 2.5 mm) pheromone-impregnated plastic flake. Aircraft drop the flakes, treated with a sticking agent, on the forest canopy and understory vegetation.

A drawback of flakes is that special application equipment is required. Pheromone-impregnated plastic beads are under development; these beads will **not** require special equipment.

Effectiveness: In eradications, mating disruption is best suited for areas that contain less than 10 egg masses per acre (25 egg masses per hectare).

Mating disruption may be used alone or with other treatments.

The use of disparlure as a mating disruptant is desirable because the pheromone does **not** affect nontarget organisms; however, the plastic containers may remain for some time before disintegrating.

Sterile Insect Release

Background: The objective of the sterile insect technique is to reduce the chance that female moths will mate with fertile males by releasing massive numbers of sterile male moths. This technique is particularly effective when sterile males are released in consecutive years; the result is fewer and fewer fertile egg masses being produced, and eventual elimination of the population.

The sterile insect technique is ideally suited to the gypsy moth: the gypsy moth has one generation per year; male moths may mate several times; female moths usually mate only once.

Use: One of three different approaches is used: (1) deploying male pupae that were sterilized by irradiation; (2) deploying male pupae that were irradiated but **not** sterilized (substerile); and (3) broadcasting eggs that had an irradiated male parent (inherited sterility). None of these approaches is without biological and logistical limitations that hamper operational use.

Deploying irradiated and sterilized male pupae requires precise matching of development schedules with wild populations; in addition, multiple releases are required.

Deploying irradiated but substerile male pupae also requires precise matching of development schedules with wild populations.

Broadcasting eggs from an irradiated male has advantages over the other two techniques: only a single release of treated gypsy moth eggs is required before wild eggs hatch; the production window is wider because eggs can be stockpiled; and the logistics of shipment and release are simpler. However, broadcasting eggs from an irradiated male has disadvantages: (1) how to predict when wild eggs will hatch and how to synchronize release and hatching of the eggs produced in the laboratory; (2) how to reduce mortality that occurs in early F_1 instars; (3) dispersal of F_1 larvae and adult males; and (4) the relative competitiveness of immatures.

Effectiveness: The sterile insect technique is best suited for use against low density gypsy moth populations, that is, those with less than 10 egg masses per acre (25 egg masses/ha).

Experimental Treatments Considered For Use in Eradications

Fungal Pathogens

Entomophaga maimaiga is a virulent pathogen and known to cause extensive epizootics in Japan. Epizootics have occurred in New England and some Middle Atlantic States. The fungus continues to expand its range entering regions more recently colonized by the gypsy moth.

Numerous constraints limit the development of *E. maimaiga* for use as an insecticide: (1) fungi are short-lived in storage; (2) fungi are relatively expensive to produce; (3) foliar applications of dried fungal preparations are sensitive to heat, humidity, sunlight, and rainfall. Formulation and application of dried fungal preparations also present unique challenges of getting adhesion to leaf surfaces and protection from adverse environmental conditions.

Parasitoids

In general, parasitoids together with other natural enemies (predators and pathogens) help regulate populations of the gypsy moth by reducing their numbers, but most researchers do not believe that they play a major role in regulating gypsy moth populations.

Predators

The gypsy moth predator community is complex and includes about 50 species of birds and 20 species of mammals, along with some amphibians, reptiles, fish, insects, and spiders. Only a few of these predators are known to affect gypsy moth population dynamics. The predators are all opportunistic feeders, which means their taste for gypsy moth depends upon the scarcity of preferred foods.

In low-density gypsy moth populations, vertebrate predators, especially the white-footed field mouse, are major sources of late-larval and pupal mortality—but not at high gypsy moth densities.

Nematodes

Nematodes that attack insects could be used in residential areas to protect individual trees from defoliation. They have provided control of several ground-dwelling and tree-boring insect species; however, results against the gypsy moth are inconsistent.

Egg-Mass Removal

Because egg mass removal is labor-intensive and time-intensive, it is impractical for large areas. Also, experience has shown that in a forested area, many more egg masses are present than are actually seen and removed.

Tree Trunk Bands and Barriers

Tree trunk bands, commonly of burlap, and barriers, commonly made of duct tape and Tanglefoot, are only useful in localized urban and suburban situations where small numbers of trees are at risk.

The bands must be checked each day so larvae can be scraped off and killed. During any outbreak, larvae remain in the canopy and feed night and day, thus reducing the effectiveness of the method.

The sticky barriers are extremely effective at preventing larvae from climbing trees; however, they have no effect on larvae already in the canopy. For this reason, the sticky barriers usually only reduce the numbers by 20 to 30 percent.

Insecticides

A number of insecticides other than *Btk*, diflibenzuron, and Gypchek are registered by the U. S. EPA for gypsy moth control. These other insecticides were excluded from use in eradications because they affect a wider range of nontarget organism than *Btk*, diflibenzuron, and Gypchek.

These insecticides may be used on nursery stock but **not** for eradication programs.

Silviculture

Once the gypsy moth becomes established, silvicultural options are reduced.

Additional Information on Insecticides with *Btk*

See the pesticide label for the correct application rates. As a minimum, two applications of *Btk* are required during an eradication; three applications are ideal. When making two applications, wait 14 days between the first and second applications. When making three applications, wait 7 to 10 days between each application.

In most cases, *Btk* is applied aerially. In small infestations (less than 5 acres), *Btk* may be applied using ground equipment. If you are considering using ground application, contact the Otis Methods Development Center for application guidance.

Foray® 48B

Foray® 48B is an approved flowable concentrate for wide-area gypsy moth programs. The label gives informaiton on ground and aerial applications.

CAUTION

Mix sticker with water before BT is added.

Foray® 48F

Foray® 48F is a flowable concentrate approved for gypsy moth Application may be by ground equipment of by air.

Foray® 76B

Foray® 76B is a flowable concentrate approved for gypsy moth. Application may be by ground equipment or by air.

Dipel® 4L

Dipel® 4L is an emulsifiable concentrate approved for gypsy moth. Application may be by ground or air.

Additional Information on Chemical Insecticides

Diflubenzuron (Dimilin®)

Diflubenzuron belongs to a group of compounds called insect growth regulators (IGR). When ingested by the gypsy moth caterpillars, diflubenzuron disrupts the formation of a new cuticle (outer skin) during molting. The caterpillar cannot complete the molting process, its body wall ruptures, and the insect dies.

One formulation of diflubenzuron is currently available. Dimilin® 4L is a liquid containing 40.4 percent diflubenzuron by weight (4 pounds of diflubenzuron per gallon of formulation).

UniRoyal Chemicals
Crop Protection Research
Benson Road
Middlebury, CT 06749
203-573-2027

Environmental Hazards: Diflubenzuron is extremely toxic to crab, shrimp, and other aquatic invertebrates. Do **not** apply directly to water or wetlands, except under forest canopy when used to control forest pests. Drift or runoff from treated areas may be hazardous to aquatic organisms in neighboring areas. Do **not** contaminate water by cleaning of equipment or disposal of wastes.

Before mixing pesticide, check and adjust the pH within the range of pH 6.0 to 7.0. You can use commercially available phosphoric acid (85 percent) to lower pH. One ounce of phosphoric acid will adjust 500 gallons of water from a pH of 9.0 to an acceptable level (between 6.0 and 7.0).

Dimilin does not need a sticker with the material and can be applied up to 2 hours before rainfall. If excessive foaming develops, cut back on agitation.

Mortality will not be noticeable until about 4 to 6 days following treatment. Look for dead larvae on the undersides of leaves. Dimilin should give excellent control of first, second, third, and fourth instar larvae.

The best time to treat is when larvae are late first and early second instar or general leaf development of one-third to one-half and continue until most of larvae are mid-fourth instar.